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# Enhancement of frequency doubling efficiency by coherent beam combining of high power diode laser amplifiers

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**Abstract:** We demonstrate enhancement in frequency doubling efficiency by coherent beam combining (CBC) of two high power tapered amplifiers. The improved frequency doubling efficiency by CBC of two amplifiers is  $\eta=3.7\%/W$  compared to single amplifier case where  $\eta=2.5\%/W$ . This enhancement is due to the better beam quality achieved by CBC. 1.8 W of blue-green light at  $\lambda = 488$  nm is generated by single-pass second harmonic generation (SHG). The obtained results confirm CBC as a promising power scaling technique in frequency conversion applications.

A compact and efficient high power blue-green laser is in high demand for many biomedical applications[1]. In the blue-green region of the spectrum from 470 nm to 490 nm, direct laser emission with good beam qualities at watt-level is very challenging. The frequency doubling of IR light is one of the most efficient ways to obtain high power light with good beam qualities in this region. However, higher efficiency of SHG process is ultimately limited by the availability of high power diffraction limited pump source with high spectral purity. Previously, power scaling techniques investigated to circumvent these limitations mostly involved spectral beam combining[2]. Here, we use CBC of two high-power tapered amplifiers seeded by a DFB laser at  $\lambda = 976$  nm (linewidth  $< 20$  pm) in Master Oscillator Power Amplifier (MOPA) configuration, shown in Fig. 1 (left), to meet the demands needed to achieve higher nonlinear conversion efficiency, thereby generating diffraction limited high power blue-green light.

A near-infrared beam power of 8.5 W with improved beam quality ( $> 85\%$  power content in central lobe and  $M_{4\sigma}^2 < 2.5$ ) is obtained by CBC of two amplifiers in MOPA configuration. This CBC-MOPA architecture was recently reported in [3].

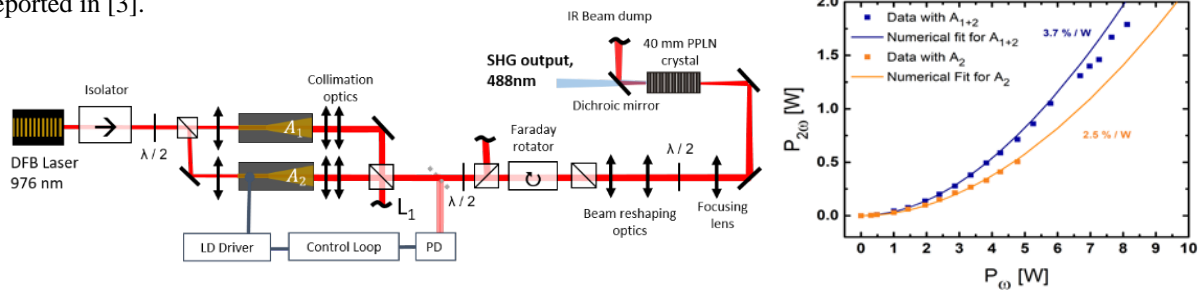


Figure 1: Setup layout (left) and SHG output power vs. fundamental input power with corresponding numerical fits using depleted pump approximation (right).

A nearly diffraction limited beam ( $M_{4\sigma}^2 < 1.2$ ) of 1.8 W of blue-green light with wavelength centered at 488 nm is obtained by single-pass SHG in a 40mm PPLN crystal with conversion efficiency of 22%. It is evident from the power curves shown in Fig. 1 (right) that higher nonlinear conversion efficiency  $\eta=3.7 \%/W$  is achieved by CBC of two tapered amplifiers compared to the single amplifier case where  $\eta=2.5 \%/W$ . This is related to improvements of the beam quality using CBC. The deviation of measured SHG power from theoretical curve beyond  $P_{\omega} \geq 6$  W is the result of thermal dephasing due to localized heating caused by SH absorption. These thermal effects can be reduced by using nonlinear crystals designed for better thermal handling in a cascade scheme. Nevertheless, the CBC-MOPA architecture shows promising results for power scaling in frequency conversion applications.

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